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Processing of Hydrophone Data for Geological Interpretation of the Sediment Pond

by

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ABSTRACT

We have processed the archived basebanded complex time series hydrophone data, over the sediment pond, that was acquired with high resolution waveform (Upsweep, HFM, 210 - 280 Hz). This data was first unbasebanded to its original band, i.e., from 210 to 280 Hz and then matched filtered with the source replica. For the purpose of geological interpretation, it was then basebanded to a lower frequency which improved the time resolution of the data. The coherent low velocity noise, that was present throughout the data set, was later removed with proper velocity filters. These processing steps helped in revealing the vertical incident coherent events and we give our interpretation of these events.

INTRODUCTION

We have processed the high resolution (Upsweep, HFM 210 -280 Hz) hydrophone data (not beam formed data) of Track 5, that is located over the sediment pond, in order to facilitate the geological interpretation of the sediment pond. In all, Track 5 consists of 30 pings, from 181 to 210, with a ping interval of 1582 m but only selected pings (188 to 192, 195, 196, 201, 204 to 208) were available for processing. Although 128 channels (including two desensitized phones) of hydrophone data were acquired for each ping, for some pings only 64 channels were available for further processing and analysis.

PROCESSING OF HYDROPHONE DATA

The hydrophone data available on tape consisted of complex time series which had been complex demodulated to save storage space. Consequently, the first task was to unbaseband the complex time series data to its original frequencies (210 - 280 Hz) and convert it to the real hydrophone data.

The complex time series data was read using the NRL/SSC Off Line Processor (OLP) and converted to SEGY (Society of Exploration Geophysicists 'Y' format) using UNIX equipment and modified software developed by Scripps Institution of Oceanography. This data was still in complex demodulated form. The SEGY data was written to exabyte tapes for storage. Additional software was written by Richard R. Slater (NRL/SSC) to convert the SEGY format to ASCII for portability. This data which was still in the complex demodulated format could now be read, unbasebanded and converted to real data by software written in PV_WAVE environment (Pflug, Caruthers and Slater, 1993).

It was decided that the first twenty seconds of hydrophone data was more than sufficient for later (geological) interpretation. The original complex basebanded data was sampled at 128 Hz and so 2560 sample points corresponding to 20 seconds were further processed. To return the complex demodulated data to its original real, high frequency band, the data was shifted up in frequency (frequency modulated) to the original 210 - 280 Hz region and

paired with the corresponding negative frequency complex conjugate mirror image. This required that the sampling rate be increased to a minimum of 560 Hz. The modulated real data was interpolated to a sampling rate of 640 (or 12 800 real sample points for twenty seconds), a rate for which the data is somewhat oversampled.

The real data was matched filtered using the original 210 - 280 Hz (Upsweep, HFM) source replica. The time zero was defined to be the origin of source transmission.

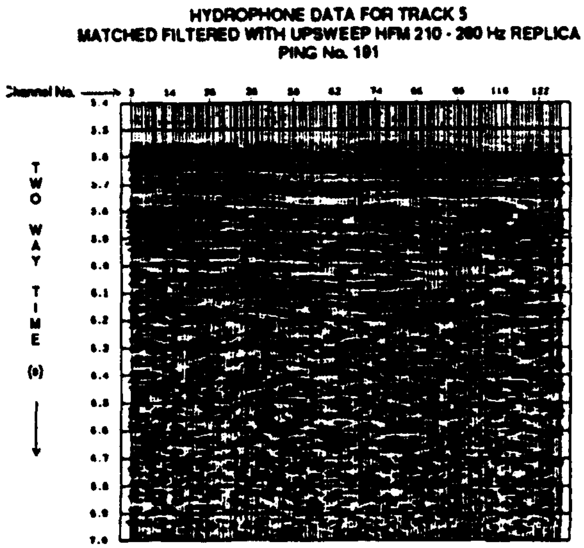


Figure 1

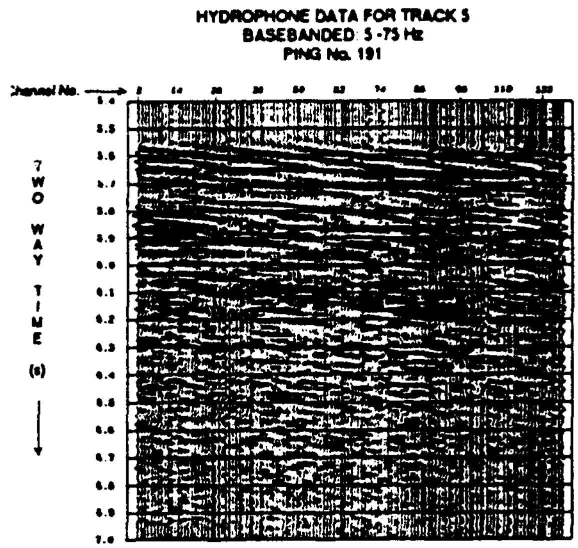
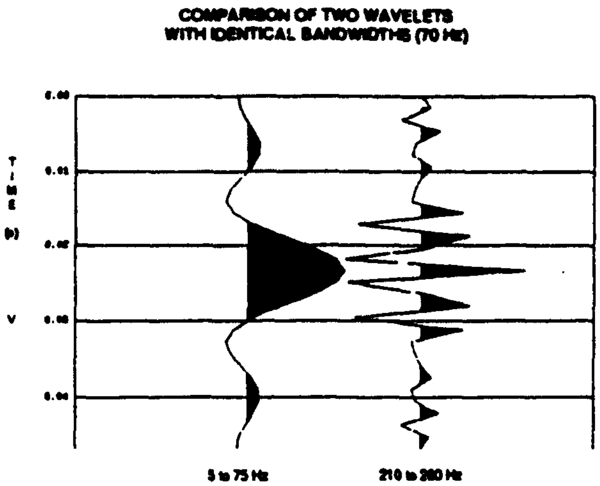


Figure 2

At this stage, a display of the high frequency wideband (210 - 280 Hz) data indicated that time domain interpretation of such a high frequency data was difficult (see Figure 1). In order to improve the interpretational aspect of the data, the real data was basebanded to lower frequency of 0 Hz. The additional step of basebanding the data involved shifting the 210 - 280 Hz positive and negative frequency regions down to 0 Hz and applying an inverse Fourier transform to obtain time-domain data. This resulted in a simpler time domain wavelet and increased the time resolution of the data set (Figure 2).

DISCUSSION ON PROCESSING

Basebanding the data to lower frequency results in a relatively higher ratio of main-lobe to side-lobe energy in time domain in comparison to the one basebanded to higher frequency. This is illustrated in Figure 3. Figure 3 shows two time-domain-wavelets; one basebanded to 0 Hz (5 - 75 Hz) and another at 205 Hz (210 - 280 Hz) with an identical bandwidth of 70 Hz. The wavelet basebanded to higher frequency (Figure 3b) exhibits a number of side lobes that are quite high in amplitude as compared to the main lobe. The wavelet basebanded to lower frequency (Figure 3a), on the other hand, indicates only one side lobe on either side of the main lobe and the side lobe energy is much lower than the main lobe. This contributes to the ease in the interpretational aspect of the wavelet basebanded to lower frequency such as the one in Figure 3a.



(a) (b)

Figure 3

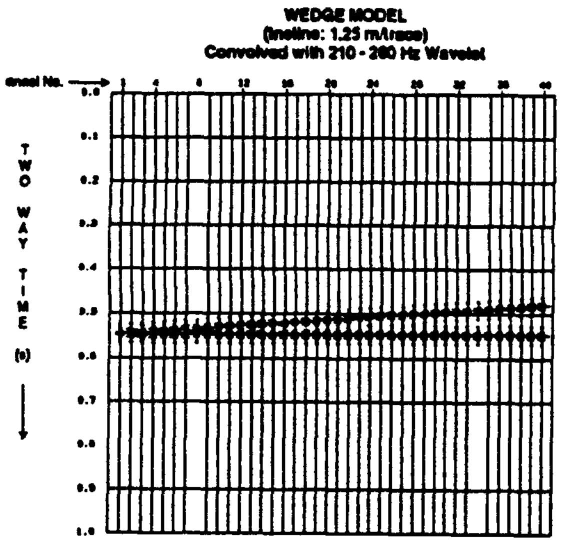


Figure 4

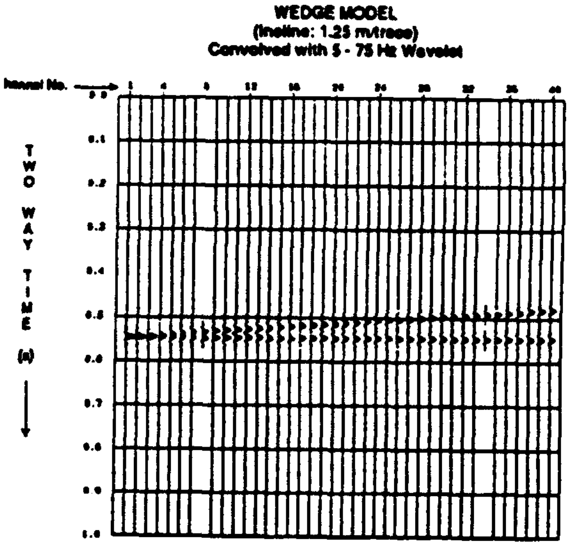


Figure 5

This was further verified by a wedge model which consists of two geological horizons, forming a wedge, indicating a varying degree of separation (thickness) between the horizons from one channel to the next. Figures 4 and 5 are the time responses to unbasebanded (210 - 280 Hz) wavelet and wavelet basebanded to 0 Hz (5 - 75 Hz) respectively. Obviously, the response to wavelet basebanded to lower frequency (Figure 5) is better able to detect the existence of two closely spaced horizons and thus exhibits better time resolution.

Next, data basebanded to 0 Hz was velocity filtered to enhance the vertically arriving events. Figure 6 shows the data of Figure 2 after velocity filtering, and it clearly has enhanced the vertically arriving events and eliminated the interfering coherent events arriving along the hydrophone array.

INTERPRETATION OF DATA

Processed data (such as of Figure 6) indicates a lot of wedge-type horizons interfering with one another. However, we do not expect such structures to be real based on geological inferences of the depositional environment in this area. This is an area where pelagic

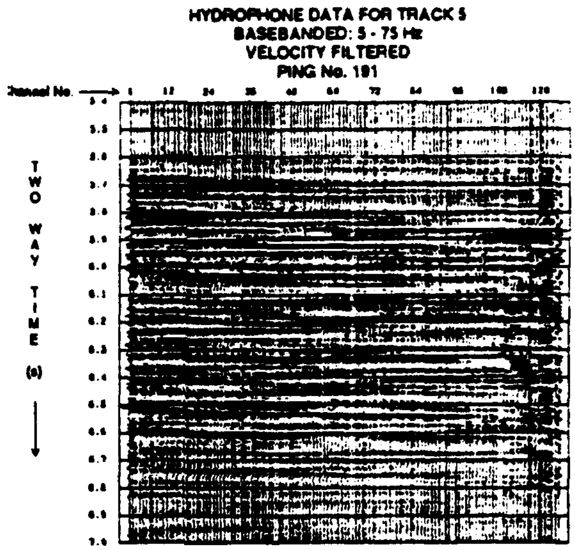


Figure 6

sediments accumulate at rates measured in centimeters per million years. These are very fine-grained sediments (mostly clay with some minor carbonate) derived from the settling of particles from the water column. Consequently, we do not expect any significant acoustic impedance contrasts within the sediments to generate the reflection events. We give below our interpretation of the data.

This data was acquired with a towed vertical array source, consisting of 10 elements with a separation of 3.66 m and the horizontal towed receiver array with a near offset of 912 m and far offset of 1224.5 m (ARSRP, 1991). With the water depth of 4130 m from the towed arrays and for the flat sea floor case, the incident angles at the receiver array from 6° to 8° approximately. The radiation pattern from the source within these angles vary considerably especially considering the presence of source and receiver ghosts. In practice, there was also coupling between the each source elements which further complicated the signal radiated by the source in the vertical direction. It was not possible to deghost the data due to the complicated source radiation pattern. Consequently, we believe that the data of Figure 6 represents in interference pattern of the complicated source signal (including the ghosts) reflected back from the sea floor.

CONCLUSIONS

It is illustrated that the time-resolution for the purposes of geological interpretation of the hydrophone data is improved when the data is processed with wavelet for which the frequency band is shifted to start at 0 Hz (basebanded to 0 Hz) in comparison to the one for which the passband starts at higher frequency. This should be true for beam forming

process too. We recommend that the hydrophone data be basebanded to zero frequency for geological interpretation and beam forming etc.

Conventional interpretation of the data does not agree with the expected geological depositional environment. We propose that the processed data represents an interference pattern of a complicated source radiation pattern (including the source and receiver ghosts) reflected back from the sea floor.

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